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ABSTRACT

Recent research has confirmed that hemispheric patterns of dominance are related to reading skills. Reading is more complex than speech because it includes a visuo-spatial element. In the great majority of people, the left hemisphere deals with speech and sequencing skills. Visual matching of printed words requires the spatial skills of the right hemisphere. The skilled reader may go directly from visual word matching to meaning without the intervention of speech patterns. The young learner, however, must proceed step by step to link spoken words with written material. When lateralization is incomplete, mixed or reversed, a conflict occurs between hemisphere dominance and the direction of scanning, leading to the reversal of letters or even words. Many researchers support the suggestion by Samuel Orton that poor readers often lack consistent patterns of dominance; an example is non-right-handed persons, who may have speech located in both hemispheres, making the normal visuo-spatial skills of the right hemisphere inadequate. (Discussion following presentation of the paper is included.) (Author/RL)

Cerebral Laterality and Reading

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CEREBRAL LATERALITY AND READING

Jane F. Mackworth

In 1937 Orton suggested that inadequate reading skill was often associated with inadequate patterns of cerebral dominance. He felt that many poor readers showed disturbances of laterality. Dyslexics might have a dominant right brain, which might lead to the mirror reversals so common in dyslexics. Recent work has confirmed that hemispheric patterns of dominance are related to reading skills.

Reading involves the cooperation of the two hemispheres. The left hemisphere is predominantly concerned with sequencing abilities, and with speech in particular. Some children may have speech centers in both hemispheres, with a resultant defect in visuo-spatial skills. Recent research has shown that the skills of the right brain are essential for reading. It can match words and letters as patterns, and plays a major part in the recognition of spelling patterns. Highly skilled readers may go directly from the visual pattern of the word to meaning, bypassing the left-brained speech skills.

Bogen (1975) has pointed out that the right brain is comprehensive, creative and synthetic, in the sense that it puts things together. It is superior on kinesthetic and tactile skills, as well as nonverbal spatial skills, such as recognition of faces, pictures, geometric shapes, and map reading. It can also connect a written word with the appropriate object. It deals with the nonverbal aspects of music, such as intonation and pitch; and may be essential in the recognition of the nature of a sentence, since intonation indicates whether the sentence is a question, a statement or a command (Blumstein and Cooper, 1974). Bogen suggests that teaching should deal with both sides of the brain, not just the left-hemisphere speech. Reading, writing and mathematics all require the cooperation of both hemispheres. Moreover, the right-brained skills of spatial matching, drawing, painting, photography, sculpture, and the ability to produce and use engineering drawings are vitally important in creative life, however little respect they may receive in school. Girls, who may be weak in these right-brained skills, particularly need training in them.

The basic relationship between the brain and the outside world is complex. In general, the left brain controls the right side of the body. However, the left brain also controls the right fields of both eyes, while the right brain controls the left fields of both eyes. Thus eye dominance is somewhat of a myth. Bruner (1963) wrote a little book entitled "On Knowing: Essays for the Left Hand", in which he discussed the teaching of mathematics. He pointed out that "the heart of mathematical learning was tipped well to the left". It is also tipped well to the male side, since very few girls go in for higher mathematics. Mathematics is a way of dealing with reality that begins with the counting of objects, and ends in an empyrean that is almost impossible to communicate in words.

There is a close relation between dreams, which are almost entirely pictorial, and creativity, especially when the answer to a problem presents itself in visual form. The right brain is closer to reality than the left, which obscures rather than illuminates by its concentration on verbal description. But since the left brain dominates the outlook of the verbal human, the right brain can only communicate its insights when the left brain has gone as far as it can and given up. Then the dreaming right brain presents the solution in an "Aha" experience. This often happens when the cortex is falling asleep. Our daytime life is time-bound, sequential activity that allows no time to stop and dream. The night-time life of dreams is essential for health, and it covers all space and time, thinking in a new way.

Cerebral lateralization and handedness.

The relation between handedness and brain dominance is by no means one to one. Most left-handers have speech centered in the left brain, just like most right-handers. Some left-handers and people with mixed dominance may have speech centers in both hemispheres. The best ways to measure dominance involve the use of eye fields or of ear dominance. Bartholomeus (1974) has described how the right ear of right-handers gives a superior result for letter and word sequences, while the left ear is superior for the recognition of a melody. When singing voices are fed into either ear, there is no difference, since the two hemispheres work in harmony.

Beaumont and Dimond (1975) reported that when abstract shapes were shown in either visual half-field, non-right handers were better at the task than right-handers. The authors felt that cerebral organization is more diffuse in the non-right hander. Thus shape recognition is better in the left brain of these subjects than in the left brain of right-handers.

Beaumont (1974) remarked that between 5 and 12 percent of the population consider themselves to be left-handed. However, the extent of left-handedness is not related to reading difficulties. These are more likely to be found in subjects with an indeterminate or mixed dominance. Output is best when spatial and sequential processes are separated to some extent in the brain. There must

teaching should deal with both sides of the brain, not just the left-hemisphere speech. Reading, writing and mathematics all require the cooperation of both hemispheres. Moreover, the right-brained skills of spatial matching, drawing, painting, photography, sculpture, and the ability to produce and use engineering drawings are vitally important in creative life, however little respect they may receive in school.
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Since the non-right hander often has speech localized in both hemispheres, there may be an interference with the proper functions of the right brain. Thus many non-right handers may perform poorly on the WAIS performance skills (Levy, 1969). On the other hand, Bogen has suggested that the reduction in SAT scores in recent years may be due to the great increase in TV watching. While most of TV deals with imaginary events, it is still more closely related to reality than verbal material. The Greeks discovered the advantage of the double brain when they invented the art of memorizing facts by linking a word with a mental picture of some familiar object in their homes. Wittrock (1975) also found that poor readers had very poor verbal recall scores even when they used imagery, achieving only 20 percent success, as compared to the 70 percent recall of the normal children. Paivio (1971) showed that imagery is the most important variable in verbal recall. Bilateral speech representation may interfere with the imaging skills of the right brain.

Laterality and reading.

Ingram and Reid (1956) found that only 29 percent of poor readers in a group of children with developmental dyslexia were strongly lateralized. Children with verbal skills that were significantly inferior to performance skills on the Wechsler had audio-phonic difficulties. Those who were inferior on the performance scale had visuo-spatial errors. Mackworth (1974) found that a group of severely disabled readers in Grade 10 made only a chance score on a spelling recognition test. Patients with right brain damage were similarly unable to recognize mispellings. Patients with left-brain damage had little difficulty with the spelling recognition, making only half the number of errors that be a reason why we have two specialized hemispheres. Beaumont reported that larger differences between response times for spatial or verbal material were found in the sub-dominant right hemisphere of right-handed subjects, while in the left hemisphere the differences between the two kinds of material were smaller. The non-right handed group showed more equal effects in the two hemispheres; people with right or mixed dominance are less lateralized than those with left brain dominance.

In a further experiment Dimond and Beaumont (Beaumont, 1974) required subjects to match English and Greek letters within and between alphabets. Performance was better when both hemispheres were used together. With increasing sinistrality, a smaller difference in response times between the hemispheres was found. In mathematics, right hemisphere superiority in subtraction was found. Sinistrality was related to smaller differences between the hemispheres, in response latency for addition, and larger differences for subtraction. Thus the brain of the left-hander seems to be more clearly lateralized for calculation. Addition was regarded as a matching problem rather than a mathematical one. In word association, Dimond and Beaumont reported that the left hemisphere produced more common responses; the non-right handed group demonstrated the more creative skills of the right hemisphere. The conclusion was drawn that the dominant left hemisphere works best with a single topic; when however the representation of skills is more diffuse, there may be an advantage for synthesis. Complex integrative operations may therefore be carried out more efficiently by the non-right hander. Thus the difference between highly lateralized dominance and diffuse dominance shows itself in an interaction between the level of complexity and integration

(1975) found that there was a left field preference for face-like patterns, but again the poor readers required more time than the good readers to recognize a pattern. The male poor readers showed a left hemifield score for letters that was superior to that of the good male readers. The female poor readers however showed lower scores than the good readers in both fields, and they also took almost twice as long as the good female readers with face recognition. The data suggest that the girls who were poor readers had a more wide-spread deficit than the boys. Marcel and Rajan concluded that the degrees of lateralization of verbal and visuo-spatial skills were not related to each other.

Silver and Hagin (1970) reported that children with reading disabilities were disoriented in space and time, in all modalities, visual auditory and kinesthetic-tactile. They also showed a lack of clear-cut cerebral dominance. Children who improved with practice on the Bender-Gestalt also improved in reading, while one-third of the group did not improve on either. Silver (1975) reported that when children with communicative disorders were taught to produce visual art, they significantly improved in the abilities of selecting, combining and representing as compared with normals who received the same instruction. Thus these handicapped children appeared to have right brain spatial dominance at the expense of left brain language.

White (1969) discussed various aspects of laterality in relation to the type of material used for testing. He noted that bilateral presentation of random letters or digits favored recall from the left visual fields, which feed to the right hemisphere. Jewish -speaking children showed superior recall of Yiddish words in the left visual fields with unilateral presentation. He suggested the right-brain damaged patients made. Both groups made 43 percent errors when asked to decide if two words sounded the same or not (50 percent being chance). It is clear that reading requires the cooperation of both sides of the brain. Bateman (1969) suggested that the phonics method is better for teaching children to read, but the ability to recognize a word by sight is an essential part of skilled reading. Ingram (1970) concluded that most dyslexics can make good progress with appropriate instruction.

Bogart (1975) found that poor spellers did not differ from good ones in patterns of cerebral dominance. There was a clear right visual field (left hemisphere) superiority for both groups in recognizing letter pairs. However, the poor spellers responded more slowly than the good ones when using their right hands, though there was no difference between the groups when the left hand was used.

Buffery (1974) described a study on 64 female college students. The right-handed ones showed superior performance with tachistoscopic words when there was an inter-trial delay of 16 seconds. However, both right and left-handed groups showed more accurate perception of words in the right visual hemifields. The dextrals were better with words than with spatial patterns and faces, but the sinistrals showed no difference between the two kinds of material. Patterns were recognized best when they were presented to the right hemisphere, regardless of the handedness of the group.

Marcel, Katz and Smith (1974) found that good readers aged 7.6 to 8.7 years showed greater right field superiority than poor readers with verbal material. Both groups of male readers showed greater asymmetry than girls. Marcel and Rajan objects that are structurally similar. Nebes points out that there is an inverse relationship between scholastic achievement, which is entirely based on verbal skills, and creativity.

Kershner (1974) examined the relationship between the visual perception of words and forms in right-handers who were also right-eyed, and those with crossed lateralization, (right hand - left eye dominance). He used visual eye fields to measure the lateralization of the functions. The highly lateralized subjects displayed superior visual perception of words but poorer form perception than the subjects with crossed lateralization. He concluded that the coexistence of linguistic and spatial visual perception in the same hemisphere (left or right) is related to lowered ability in the specialized function of the opposite hemisphere. The groups with crossed or unilateral ocular-manual skills are normal manifestations of contrasting patterns of neurological organization, with a unique bias towards spatial or linguistic perception. The child who is spatially superior should be taught with emphasis on spatial skills, so that he can use his ability to earn his living.

Levy (1974) reported that left-handers with normal writing made significantly fewer errors in matching words with pictures when the words were presented to the left fields. Normal right-handers showed a nonsignificant right field dominance, while the left-handers who wrote with the hand inverted showed a non-significant left-field superiority. Levy suggested that this lack of significance was due to a conflict between hemspheric dominance and scanning direction. In a dot location task all the subjects performed better with the right hemisphere.

Levy suggested that the proportion of dextrals in the that laterality differences might be due to the unilateral presentation. Outline drawings of common easily named objects are dealt with better by the left hemisphere, but facial recognition is dealt with better by the right hemisphere. With auditory material, the spoken names of digits are dealt with by the left hemisphere, while the right hemisphere deals with music.

Patients with right brain damage show considerable problems with reading. They have marked left-sided neglect, and tend to begin to read or write in the middle of the page. In reading the gaze will fail to return to the beginning of the next line, and may even omit several lines. In writing, the material begins in the center of the page, and slopes up towards the right.

Cohen (1972) reported that the right-handed subject takes only 84 msecs longer to match letters by name (Aa) than by visual similarity, when using the left hemisphere. But when using the right hemisphere there is a difference of 181 msecs between name and visual matching, since the right brain is better at matching by shape, and worse at matching by name. Left-handers show a reversed asymmetry, but the differences are less consistent. Cohen (1973) reported that when sets of letters were presented to either hemisphere, the left gave response times that increased with the number of letters. The right hemisphere showed no such increase; it used parallel or holistic processing, in contrast to the sequential processing of the left hemisphere. When unnamable shapes were used, both hemispheres processed in parallel.

Nebes (1975) showed that injury to the right hemisphere gives spatial disorientation. The patient cannot use or draw maps, he misjudges size, distance and direction of objects. The left hemisphere matches objects on the basis of use, rather than verbal factor, but inferior on the performance scores. People with a dominant right spatial brain do not normally go to college. They are to be found in the ranks of the creative artists, as Gardner (1975) has pointed out. Many dyslexics have become famous, such as Edison, Patton, Harvey Cushing, and Rodin. Hans Anderson never learned to spell. Children wh[illegible]yslexic problems may do well in college if they can have their information on tape. Gardner suggests that ideographs may be useful in the teaching of dyslexics, since the ideograph can be recognized by the right brain without the need to translate a sequence of letters.

Bannatyne (1971) has pointed out that there is no relation between crossed eye-hand dominance and reading ability, but dyslexics may show a left foot dominance. This measure may be less influenced by training than handedness. In a group of dyslexics he found that 70 percent of the boys showed a preference for spatial rather than verbal activities. Dyslexics are often poorly lateralized, and may have problems with left-right orientation.

McKeever, Gill and VanDeventer (1975) reported that right-handers showed right field superiority for letter stimuli, while left-handers showed a much smaller difference between the fields. There were no differences between the speed of response to the two fields when dots were used.

Miller and Turner (1973) carried out a study of the development of laterality in relation to word recognition. Significantly better recognition in the right field was found from Fourth Grade up. Regardless of age, the hemifield differences were related to reading achievement scores. They concluded that the results favor visual laterality, reflecting internalization of scanning patterns rather than the cerebral lateralization of general population is about 89 percent. Almost all of these have left hemisphere language. 56 percent of the sinistrals have left hemisphere language, and44 percent have right hemisphere dominance. However, the lateralization is not as complete as these figures suggest. In 35 percent of the dextrals, lesions in the language area of the left hemisphere may produce only a transient aphasia or none at all. The same results follow left-sided lesions in 65 percent of the sinistrals, (Luria, 1974). In children and about a third of adults with left hemisphere damage the right hemisphere can take over the language function. Sinistrals are more likely to become aphasic after a lesion to either hemisphere than dextrals, but are also more likely to make a complete recovery. In certain cases hand and brain may show an uncrossed laterality. This may be found in left-dominant sinstrals and right-dominant dextrals.

Levy (1974) tested patients whose hemispheres were disconnect by cutting the corpus callosum. The subjects were asked to point to a picture which rhymed with another (e.g. toes-rose). They chose the right field stimulus on 80 percent of the trials, using the left hemisphere, since they were matching by name. When they were asked to match a printed word with one half of a chimeric word (e.g. deed - de/on); the subjects chose the left side of the chimera on 93 percent of trials, showing that they were matching by shape in the right hemisphere. Levy suggested that reading in the adult may be a right hemisphere function. Dyslexia may occur following either right or left hemisphere lesions.

Levy (1969) found that in a male graduate population at Cal Tech dextrals achieved verbal IQs of 138 and performance IQs of 130, while sinistrals showed IQs of 142 and 117 respectively. The sinistrals were significantly superior to the dextrals on the normals. He concluded that recalling backwards requires a visual rearrangement of the material. All patients were able to recall digit spans forwards.

Peterson (1974) arrived at the same conclusion when he asked college students to solve anagrams presented in two typefaces, Gothic and Old English. The problems presented in the familiar Gothic were solved more quickly than those in unfamiliar Old English. The effect was enhanced with more difficult anagrams. He concluded that the mental rearrangement of the letters involved a visual component. Subjects remarked that the Old English was difficult to visualize and difficult to recognize when the correct solution was reached. These data confirm the importance of the visuo-spatial aspect of reading.

Even with auditory material, perceptual lateralization may not be found when the material is nonverbal. Oscar-Berman, Goodglass and Donnenfeld (1974) carried out an experiment using pitch contours: different contours were presented simultaneously to the two ears. The subject was asked to point to a visual pattern of the pitch changes. First ear reports were more accurate for the right ear when no special instructions were given. But when the subjects were told to report one ear first, the left ear was superior for both first and second ear reports. It was concluded that there was a greater sensitivity to lateralization by the storage mechanism than by the perceiving mechanism. The use of a verbal label did not change these results. The right hemisphere appeared to be more sensitive than the left for analysis of non-linguistic sound. This was ~~true even~~ when attention was programed towards one ear or the other. The conclusion was drawn that the right hemisphere is better equipped than the left to hold some nonverbal auditory stimuli in storage.

language. When the reading scores were partialled out, the correlation between laterality and word recognition was zero. The greatest increase in the strength of the hemifield difference was between Grades 4 and 6.

Sequencing and Language.

Sequencing is carried out predominantly by the left hemisphere. One of the major problems of dyslexics is the ability to read letters and words in the correct order. Reversing letters within a word is common. Blank and Bridger (1967) studied the matching of various auditory and visual codes and concluded that the basic problem for poor readers lay in the difficulty in matching a spatial to a temporal pattern. Since the right hemisphere is mainly concerned with spatial material, while the left hemisphere deals with sequencing, reading requires the close cooperation of the two hemispheres, especially in the learning stage. Bryden (1972) confirmed that poor readers had a particular difficulty with matching spatial and temporal sequences, and were worse than good readers on all matching tasks. There was a high correlation between reading ability and matching skills for the poor readers but not for the good ones. The presence of language skills in both hemi-speres might interfere with the spatial skills of the right hemisphere.

Corkin (1974) tested boys from 6.5 to 11.9 years of age. They were asked to copy the order in which the experimenter tapped cubes in a series. Poor readers were as good as good readers, but when a delay was introduced between the example and the response the poor readers were inferior at all age levels. Corkin suggested that the poor readers might have inadequate memory spans.

Costa (1975) studied the relationship between brain damage and sequencing. Both right and left hemisphere damage resulted in difficulty in recalling a digit span backwards., as compared with

In the serial memory task the aphasics were unable to reach criterion when five stimuli, each 75 msecs in duration, were presented at intervals of 428 msecs. With the longer tone of 250 msecs, two subjects out of 12 aphasics reached criterion. Normal speech occurs at about 80 msecs per phoneme. At this rate of input, aphasics are unable to process correctly simple sequences of non-verbal tones. The defect in rapid auditory processing may have its greatest effect on the analysis of the rapid formant transitional information which charaterizes certain phonems. Tallal (1975) studied the ability of developmental dysphasics to select tokens on command (blue circles, red squares, etc). The test presented few difficulties to normal 8.6 year old children. As the demand on auditory retention increased, the performance of the dysphasics decreased. Their language problems seemed to stem partly from the auditory perceptual inability.

Posner, Lewis and Conrad (1972) discussed the process of reading in relation to the three isolable codes: visual, phonemic and semantic. Semantic problems are found mostly in dysphasics, as described above. The phonemic coding from visual to speech motor programs or to some abstract representation of the name is the central problem of reading. Every child must learn the arbitrary relationship between the spoken word and the written one, and most do this easily. Often they have been in contact with the written word from an early age, and have watched their mothers read from a simple ABC rhyme book, following along with her voice. Others may lack this early experience, by which the important coding process is discovered almost by accident. The poor reader, however, may be unable to make this link between visual and spoken words, because of some unusual distribution of the essential skills.

Myklebust (1973) has reported that reading disability children are often deficient in the ability to comprehend and to use language. These two problems are separate. He found that 84 percent had positive neurological signs. Locomotor coordination was often deficient. Such children can be distinguished from the pure dyslexic, who does not give any indication of generalized deficits. He has however a familial history of dyslexia.

Moore and Weidner (1975) studied dichotic word-perception skills of aphasic and normal adults. When the injury was less than six months previous to testing, there was no ear preference. After six months, there was a significant left ear preference. The controls showed a right ear preference. It was clear that there was a shift in hemispheric dominance when the left language center was destroyed, but this shift took about six months. These aphasics did just as well when they had to make an oral response or to respond by pointing.

Tallal and Piercy (1973) studied children with developmental aphasia, using both auditory and visual sequences of non-verbal stimuli, tones or dots. No significant difference was found between the visual scores for the aphasic and normal children. On the auditory tests, the aphasics were no different from the controls when there was an interval of 428 msecs between two tones. However, as the tones came closer together, there was a decrease in performance of the aphasics; this decrease interacted with the duration of the tone. Performance fell to about 60 percent of normal when the duration of the tone was reduced to 75 msecs and the interval to 150 msecs. As the number of stimulus elements increased, there was a marked reduction in the correct responses given by the aphasics. The responses were made by pushing one of two panels to copy the sequence of tones.

The Bender-Gestalt Test is said to differentiate between good and poor readers. This visuo-spatial set of shapes is often copied very inadequately by poor readers. Such a failure to process designs is probably related to some deficiency in the right hemisphere, possibly due to the localization of speech in both hemispheres. Koppitz (1975) reported that the Bender-Gestalt differentiates between learning disability children, but not between good and poor readers. The Visual-Aural Digit Span discriminates between good and poor readers, but not between learning disabled readers and controls. Many poor readers may also be learning disabled. Such children have a very short attention span. The hyperactive child can often be brought to a normal level of function by the use of appropriate medication. Bannatyne (1971) has pointed out that children with difficulty in attention need to work in a modified environment, where there is a minimum of distraction. They need careful programming, with tangible rewards for each successful activity.

Bannatyne (1971) points out that the familial dyslexic is quite different. He has a specific disability. Such children are often strong in spatial tasks and weak in sequential ones. They may perhaps have a dominant right brain. In contrast to the children with minimal brain damage, they do not show motor-kinesthetic difficulties. Their severe sequencing problems interfere with both speech skills and listening skills. They have difficulty in determining the sequence of musical sounds, and in distinguishing between vowels (e.g. pen and pin). Many such children can sound out a word phonetically, but cannot blend the phonemes together to recognize the word. They also have great difficulty in linking

Posner et al (1972) reported that it takes longer to match letters or words by name than by sight, and longer still by class (vowels or consonants; plants or animals). The physical match is affected by visual confusion, decay or rotation, and when so disrupted the name match may be faster than the physical one. The name match is affected by acoustic confusion or other stored names. The visual code preserves the spatial organization, while the name match goes from left to right. When all items are the same visually, it does not matter how many there are, but when they are similar only in name, the match taks 60 msecs longer per pair of letters. Thus the right brain makes the spatial match when the letters are identical, but when they must be named the left sequential brain takes over.

There is a marked effect of familiarity of spelling patterns, when working with good readers. The subject can match a string of letters for physical identity much faster if they form a familiar word. Such word familiarity effects are as great in deaf children as in the hearing child, showing that this effect is due to the visual match. Bruner, Olver and Greenfield (1966) argue for the importance of iconic representation in learning to read.

The name code is the same for visually and orally presented letters and words. However, the young child has to learn the relationship between these two methods of presentation, and for most children the cross-modal learning is the major problem in reading. However, for some children, the difficulty may lie in learning the visual aspects, such as letter worder within words, and letter orientation. Aphasic children may have a difficulty due to their inadequate command of language. The emphasis in teaching may thus be different for different children.

who had undergone unilateral temporal lobectomy one to seven years before testing. All were left hemisphere dominant for language. They were shown three-letter words written vertically to reduce scanning. Nonsense forms were also used. The right temporal group was impaired in the recognition of written words and random designs in all field. The right temporal lobe is essential for maximum functioning of visual recognition, both words and patterns. These subjects took twice as long as normal or left hemisphere damaged patients. All the subjects took longer to recognize the verbal material than the nonsense patterns. The words were often reported as separate letters, since the vertical alignment was different from the normal pattern.

Several writers have discussed the possibility of using a more unitary method of presenting written words to reduce the sequencing problem. Rozin et al (1971) were able to teach children with reading problems in second grade by representing the English words with Chinese characters. They suggested that reading disability can be accounted for in terms of the abstract nature of the phonene, and that the syllable might be nore useful. However, most primary reading material usually consists of one syllable words. How far there would be transfer from the characters to the normal print is questionable.

Kolers and Perkins (1969) made detailed studies of the relationship between the visual aspects of print and the speed of reading. They found that various transformation of print produced different degrees of interference in reading. Simple rotation of individual letters allowed easy recognition of the letters. Mirror reflections were easier than inversions. Neither direction of scan nor orientation of letters accounted for performance individually, but the interaction of the two factors was important. It was not a phoneme with a grapheme. The main effort in working with these children is the memorization of phoneme-grapheme matches within words as a squence of sounds (Bannatyne, 1971).

Zurif and Bryden (1969) investigated the relation between familial handedness and left-right auditory differences in auditory and visual perception. They found that right-handers and non-familial left-handers showed a right-sided dominance for letters on all tasks. The familial left-handers were better with left-sided presentation. It was concluded that cerebral dominance was indeterminate only in familial left-handers.

Zurif and Carson (1970) studied dyslexics with various perceptual tasks. The dyslexics were significantly inferior to normals in dealing with the temporal aspects of nonverbal auditory and visual information. They were also worse on tests of manual dexterity and dichotic listening. The dyslexics showed dominance of the left ear, in contrast to the right ear dominance of normal readers. The measures of reading skill, temporal analysis and dichotic listening were significantly related to each other.

Stanley, Kaplan and Poole (1975) tested dyslexics with spatial and sequential processing, and found that there was no difference between the groups when they were asked to make a visual match with spatial transformation. The children, aged 8-12 years, also showed no differences between groups in relation to tactual serial matching. Both these activities are normally carried out by the right brain. However, the dyslexics were inferior on visual sequential memory and on auditory sequential matching.

The importance of the right brain in reading was demonstrated by Rosenthal and Fedio (1975). They studied patients three transformations were those read most rapidly, and they accounted for 481 out of a possible 504 predicted inequalities between reading speeds. It was concluded that the component skills required involved rotation, ordering of elements and sensitivity to relationships between elements. The component skills learned in previous transformations can be recombined to help in reading new transformations. Errors were often due to a temporary failure to apply the appropriate transformation, so that material was read in a more mechanical application of earlier learning. Such misreadings may account for some of the errors made by dyslexics. Their shaky frame of reference may include competition between the right and left brains, and result in failure to recognize the orientation of letters or their order within words. Is this problem related to the inadequate spatial representation that may result from bilateral speech centers? Studies of such spatial transformations used by Kolers might be used with visual fields, to discover the relative parts played by the two hemispheres.

The work of Kolers and his colleagues has shown that the brain is extremely skilled in learning new orientations of the written word. Perhaps this ability to recognize a letter in a new orientation is not surprising, since we learnt in our cradles to recognize a face or an object in any orientation. Richardson (1974) has discussed the importance of the Cartesian frame of reference in relation to dyslexia. He pointed out that there are six signs of dyslexia which may be due to the lack of a visual frame of reference. These signs are letter reversals, form recognition of objects independent of orientation, defective visual sequential scanning, poor visual balance, failure to acquire nonspatial ordering relationships, including temporal relations and tenses, and finally possible to specify formally the aspects of the letter that were used by the subject to decide on its nature.

Kolers (1975) showed that the recognition of sentences involves not only a memory of the words but also a memory of the visual aspect. He presented sentences that were written either in the normal orientation or inverted. After reading a sentence the subject was asked to read aloud a varying number of other sentences and then to read the intitial sentence again, in an inverted orientation. The measure was the time taken to read the experimental sentence in its two exposures. The time depended on the orientation of both sentences. He found that when the first orientation was normal and the second inverted, it took six times as long to read the inverted sentence as to read the first normal sentence. When however both sentences were inverted, the second was read faster. — The first exposure to the inverted orientation allowed some learning of the visual aspects of the sentence. Kolers concluded that pattern analysis at the graphemic level is an essential part of the reading process, and recognition may be accounted for without recourse to semantic contents. Once again the skills of the right brain are seen to be an important part of reading. However, the ability to use the orientation of letters for information is a secondary skill that many children may have difficulty in learning.

Kolers and Perkins (1975) discussed the ability to read text transformed in various ways, and concluded that the visual system bases its decoding on three "subroutines". The first transformation involves the simple inversion of each line, so that the inverted words must be read from right to left. In the second transformation, the passage runs from left to right, but each letter is reversed. In the third, the passage runs from right to left, with each letter reversed. These which includes speech, requires precise coordination between flexion and extension, and very exact placing of the eyes, tongue and fingers. Kinsbourne points out that the dominance of the left brain for all these sequences of movements in time is clearly of great importance. Conflict between the two hemispheres might lead to strange results, especially if the right brain is a mirror image of the left.

Kinsbourne and Warrington (1966) tested two groups of disabled readers. The first group was male, with a nonverbal IQ 20 points higher than their verbal IQ. The second group of 5 girls and 2 boys had verbal IQs 20 points higher than their nonverbal IQs. In the aphasic Group I reading and spelling levels were the same, about 3-7 years below chronological age. In Group II spelling was one year below reading level, and there was difficulty with writing. No patient in Group I failed the finger test, but all those in Group II failed. Five of the patients in Group II had a history of birth injury. This group showed minimal sequencing skills and difficulty with arithmetic. Kinsbourne and Warrington pointed out that such children with cortical deficits form a minority in the reading disability population.

Gazzaniga (1974) suggested that the right hemisphere remains language rich until the teens, but later the left hemisphere inhibits the language skills of the right brain. Performance dominance in one hemisphere inhibits that skill in the other. Word matching by sight is carried out more effectively in the right hemisphere. When the words in a sentence are concrete and highly imagable, the right hemisphere is active in developing a pictorial image from the verbal material. Olson (1973) reported that when dominance is poorly established, there is no difference a performance IQ that is better than the verbal IQ. These backward readers may have a poor conception of vertical and horizontal in space. However, it should be mentioned that there is no evidence that teaching children to balance on a beam improves their ability to read. Mattis, French and Rapin (1975) found that there was no difference between brain damaged dyslexics and those without identifiable brain damage in regard to language and writing problems.

Relation between verbal and performance IQ.

Verbal IQ is usually a direct function of the left-brained language center, while performance IQ deals with aspects of performance such as spatial and tactile skills that are related to the right brain. Kinsbourne (1974) discussed the mechanisms of hemispheric interaction, and concluded that the function of the whole seems to be less than the sum of its parts. Less deficit may be found when a whole hemisphere is removed than when there is a focal lesion in that hemisphere. No difference is found between the hemispheres with regard to verbal intelligence. The right hemisphere is quite capable of decoding or understanding quite complex speech, even though it cannot talk. Lateralized lesions in children rarely cause a substantial loss of receptive language. Brown and Jaffe (1975) have suggested that receptive lateralization may be slow to develop, and may increase throughout adult life. The competence of the right brain for decoding speech may include both the auditory and visual modes, and its semantic and syntactic competence may not be greatly inferior to that of the left hemisphere. Lateralization for output seems to be much more important than lateralization for input. The muscular system, were more likely to show crossed ear-hand dominance than good male readers. A similar effect with girls was found only in Grade 2.

Tactile Skills.

Since many dyslexics have mixed or right brain dominance, some workers have suggested that the kinesthetic skills of the right brain might be useful in learning to read. Hermelin and O'Connor (1971) found a left-hand superiority for reading Braille. The Braille reader moves his right hand ahead while actually reading with the left. McCoy (1975) worked with a 15 year old female who could neither read nore write. She was taught to read Braille and improved rapidly. Rudel, Denckla and Spalten (1974) taught children in Grades 2 through 8 to read Braille, using a paired associate method. They learnt six letters with the left hand and six with the right hand. Learning was better when the left hand was used, even though all the children were right-handed. The actual recognition of the Braille letters was therefore carried out better by the right hemisphere, even though this recognition must be followed by the use of the verbal skills of the left hemisphere.

Witelson (1974) tested right-handed boys aged 6-14 years with tactile shapes, which were letters or nonsense shapes. The subject was asked to feel two shapes simultaneously, one in each hand. He gave his answer by pointing to the two shapes or letters in a recognition display. Even the six year old boys showed specialized left-handed skills for recognition of nonsense shapes.

between the verbal scores for left and right visual fields. Dyslexics achieved as good an overall score as normals, but showed no lateralization effects. However, there may be competition between the two cognitive systems.

Klatzky and Atkinson (1971) reported that letters are matched better by the right hemisphere in normal subjects, while pictures that must be named are matched most rapidly by the left hemisphere. Cross-linked spatial and naming skills take longer. Thus the usual finding of maximal left-hemisphere performance for verbal material and right hemisphere skills for pictures is contradicted when the response requires the use of the opposite hemisphere. That is, the right hand is used for spatial material and the left hand for verbal responses.

Klisz and Parsons (1975) tested left handers with tones. These are normally dealt with by the right hemisphere. Ten out of 16 showed left ear preference, indicating the same lateralization as right handers. The six subjects who showed right ear preference had significantly smaller inter-ear differences, and a greater tendency to mixed hand preferences. These subjects showed evidence of mixed laterality. Amytal studies have shown that 60 percent of left-handers have the typical pattern of left hemisphere speech and right hemisphere nonverbal skills, thus having the same internal lateralization as right-handers.

Dichotic ear tests wre particularly useful in determining the location of the speech center, which is normally found in the dominant hemisphere. Testing for visual fields is more ambiguous, since the visual matching of words may be carried out by the subdominant hemisphere. When letters or words must be matched by name, the dominant hemisphere carries out the task.

who talk early, this would indicate that there was an inhibiting effect of the speech center on the development of spatial skills.

Porac and Coren (1975) discussed the laterality of eye and limb in relation to dominance. They found that males showed a more consistent relationship between eye and limb preference, together with a stronger eye dominance. This consistency was higher for males with right eye dominance than for those with left eye dominance. Right eye dominance was shown by 38 percent of females, while 25 percent showed left eye dominance. There was no correlation between dominant eye and handedness for females, while there was a low but significant correlation for males. Aaron and Handley (1975) found that girls aged 4.6 years developed a left to right scanning strategy about two years before boys (6.6 years).

It is believed that non-right handedness, related to mixed or right brain dominance, may represent a failure to achieve the normal pattern rather than an equally efficient mirror image. Boys are more likely to show left-handedness than girls.

Boys are the weaker sex. More boys are born than girls, but the boys show a higher death rate in early life, so that by maturity the ratio is approximately equal. In later life women are in the majority, due to the earlier death of males. Males differ from females in the absence of a second sex chromosome. Their one sex chromosome comes from the mother. Most genetic dyslexics are male (Bannatyne, 1971). The proportion of boys to girls with mild disability is 3:1, while in the group of severely handicapped dyslexics there are ten boys to one girls. A number of these poor readers may have superior spatial and motor skills.

The most common lateralization shows the presence of speech but no difference was found between the hands in letter recognition. Witelson concluded that linguistic information is analyzed first into a spatial code and then translated into a linguistic one. He considered that tactile remedial techniques may be unhelpful, especially for children with inadequate spatial processing, since ther is no direct link between tactile input and linguistic skills, in contrast to such a link in visual and auditory modalities.

Varney and Benton (1975) studied tactile perception in relation to handedness. The right-handed subjects could perceive the direction of movement of a stimulus on the left hand better than on the right, since the right brain deals with tactile material to a large extent. Left-handed subjects showed no trend. Right-handed subjects with a left-handed parent also showed no difference between the hands. Left-handed subjects with a left-handed parent showed right-handed superiority for the tactile stimulus, but those with right-handed parents showed no asymmetry.

Lateralization and the sexes.

The growth of lateralization is an important factor in learning to read. Girls tend to become lateralized in speech earlier than boys. Boys who have reading difficulty may be considerably delayed in speech lateralization (Maccoby and Jacklin, 1974). Buffery and Gray (1972) have suggested that spatial skills are more likely to be located in both hemispheres; The weaker male laterality encourages the spatial skills. Girls are more skilled than boys on verbal tasks; in adult life women can compete with men in the creative skill of writing novels. Sherman (1971) suggested that the female early skill with words inhibits the development of right brain skills such as art or music. If boys who talk late have better development in spatial skills than boys still be trained in other skills that will allow him to earn a living. There is perhaps an overemphasis on verbal skills in school, though they are not necessarily the most profitable in later life. Man lives in two worlds; he needs the three R's to deal with time, and the three I's of Imagination, Invention and Inwardness, that deal with eternity, from which comes the creative newness that may change the world.

in the dominant left hemisphere, while the right hemisphere is concerned with visuo-spatial and motor skills. Both right and left handers may have this arrangement. Some children, mostly male, may show right hemisphere dominance, with highly developed spatial skills. Others may have speech represented in both hemispheres, with poor spatial skills. Both these groups may have poor reading skills. Zangwill and Blakemore (1972) have reported that such children may show a strong tendency for the eyes to move as much to the right as to left in reading. They may show mirror imaging of letters and words. Hecaen and Ajuriaguerra (1964) pointed out that dyslexics are often poorly lateralized. It is clear that there is a strong genetic factor in reading disability, Any interference with the normal skills of the two hemispheres will reduce reading skills.

Conclusions.

There are many causes of poor reading, but it is clear that unusual lateralization is an important one, especially in the worst readers. Such abnormal lateralization may arise from genetic factors or from brain damage before, during or after birth. Adequate performance depends on the cooperation of the two hemispheres, each contributing its own special skills. In reading, the right brain recognizes the visual pattern of the words, while the left brain links the words to speech. The right brain is spatial, the left brain deals with sequencing skills. As the reader develops his reading skills, he comes to depend increasingly on the right brain, leaping directly from the visual display to the meaning of what he reads, without ever going through the speech mechanisms until he comes to an unfamiliar word.

The child who will never learn to be a good reader can

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June 8--P.M.

OPEN DISCUSSION OF MACKWORTH PRESENTATION

GORDON: When you were talking about the differential function of the two hemispheres, were you suggesting that their functions are differentiated or their structures are differentiated?

MACKWORTH: Both. There is a speech center in the left brain and no speech center in the right brain, so in that sense the structures are different, but otherwise there is not much difference between them physically. But they do have different skills.

GORDON: Now, there are some people who assert that if one can split--disengage one hemisphere early enough, the other hemisphere can compensate for all of the functions of the cancelled hemipshere.

MACKWORTH: This is perfectly true. I know there is evidence on this. We are more interested in the normal distribution of skills, rather than the unusual.

GORDON: Does that suggest, then, that the differentiated functions are likely to be a product of the experiences of a typical human being, and therefore manipulable?

MACKWORTH: Well, speech is certainly typical of human beings, I have to agree. I don't think that teaching a child to speak alters the distribution of his brain functions. I think that he has this area in the left brain which is ready for speech, which probably begins to be activated even before he is born. That's where the speech is, in the left hemisphere.

43

GORDON: But is speech one of those functions that can be developed in the right hemisphere of an organism that has had the left hemisphere done away with?

MACKWORTH: Yes, if it's done early enough, it can happen.

GORDON: So that most of the functions of either hemisphere, then, can be generated by special experience?

MACKWORTH: Well, so it appears. But the distribution between the two hemispheres appears to be the optimal arrangement in the specialized fields.

GORDON: You make a great deal of the importance of giving greater attention to the development of the right hemisphere. Have you worried about the possibility that hemispheric dominance serves particular purposes, and the greater equalization of it might interfere with the advantage that is achieved by the establishment of dominance?

MACKWORTH: No, I don't think so. Because if you train the skills of the right brain, then the person will get better with those skills, but it won't interfere with the left brain. Why should it?

GORDON: Well, I don't know. But I was thinking that it would be that the specializations that develop in the right hemisphere may be a function of the dominance of those specializations that develop in the left.

MACKWORTH: That's true.

GORDON: I am disturbed: Thinking logically and speculatively now, does this differential distribution of dominance have any dialectical effect on the operation of the total system?

MACKWORTH: I don't know why it should. I mean, each has its own skills. The right brain is definitely dominant for visual information, as you have seen in these pictures. It's not dominant in the sense that it will control the right hand (though it does control the left hand), but it's dominant in the material that it's best at processing.

TRABASSO: When does lateralization occur?

MACKWORTH: It begins soon after birth, I think, if not earlier. In fact, in fetal brains you find a slightly enlarged area where the speech is going to develop.

TRABASSO: When is it completed?

MACKWORTH: It goes on increasing throughout childhood, some people say it's completed at 12; other people say it will go to 20 or so. So I don't think you can answer the question.

TRABASSO: How reliable is the measurement of lateralization? That is, how good, what would be the classification of a lateralized versus a nonlaterialized child?

MACKWORTH: Well, most of them are lateralized one way or another, but how accurate can you be in determining that? It would be interesting to find out.

For instance, if you give the spatial tests for the right brain, and you find that the child doesn't do them too well, then you can conceive that their lateralization is different from normal. Similarly, if you give verbal tests of the left brain, they don't do them too well, maybe they have got them in the other brain.

TRABASSO: When you have clear evidence of brain damage in one of the hemispheres, then you seem to indicate clear differences in certain performances, which by and large have to do with visual and spatial processing.

MACKWORTH: And also with the verbal processing.

TRABASSO: I think that we can accept that, along with the other evidence for lateralization and specialization in function. What I am concerned about is the implications of your work, with respect to normal children with no evidence of brain damage, who fail to read, and whether or not the source of reading difficulty is a physiological one; that is, either failure to lateralize or possibly undetected brain damage.

Are you indicating that perhaps some proportion of children who have difficulty learning to read, may have a failure of lateralization? Is that one of the implications of your paper?

MACKWORTH: I think it's a possibility, but I certainly don't have the data on that, but I would like to try and find out.

TRABASSO: Can lateralization be trained? That is, if a child is diagnosed as not being lateralized, is it possible by arranging various kinds of experiences, to bring about lateralization?

MACKWORTH: I think of speech in both hemispheres, I think you would have problems. I very much doubt whether lateralization is something that should be trained, because it's being trained according to some sort of theory you have, but you don't really know whether it has anything to do with reality.

FISHER: Lenneberg (1967) and Geschwind (1972) have pointed out that the 12th year represents a relatively critical period for switching hemispheres. Zaidel (1974) devised a technique for examining lateralization using what he calls the Z-lens. This lens can impose a "peripheral vision effect," which for normal reading adults, has demonstrated a vocabulary of a 14-year-old and syntax of a 5-year-old to exist in the right hemisphere. There is then some degree of language in the right hemisphere. Whether it remains a continually cooperative language or whether it terminates development at 14, remains to be seen.

MACKWORTH: Well, I understand that language in the right brain is not a spoken language, it's a visual language. The right brain recognizes the word, on the page, but cannot sound it out.

FISHER: It seems to be a visual interpretive language derived from sampling the printed text.

MACKWORTH: Yes, because the right brain can't talk.

FISHER: That's what I was pointing out from the visual study. There are also some important implications for sex differences. There are some difficulties with boys on the assumption that lateralization develops much more slowly in boys. As it turns out, in the early grades we find the high predominance of poor readers being boys. There are additional problems with a strict lateralization hypothesis, and Brenda Milner has pointed some of these out. One example occurs when looking at left-handed girls, and mixed dominance girls in particular, because they behave quite strangely. For as it turns out, the normal decrements that might be expected as a result of lacking or mixed hemispheric dominance, just does not show up as a deficit for girls. But when right hemisphere or mixed dominance is apparent in boys, there is high risk of decrement.

MACKWORTH: There is no doubt about it, the older they get, the more boys there are relative to girls in the poor reading class. The ratio is about ten to one, by the time they get into high school.

GUTHRIE: Measurement is very, very difficult here. For instance, in dichotic listening tasks, measuring of right ear dominance for language materials is a very tenuous business, and subject to a very large number of small methodological variations. The work of Bryden and Kemuro and others on these tests shows that the effect is rather subtle. The right ear dominance is there under certain conditions, and we don't fully know why it fails to appear under others. So that the dominance that appears to be present for the left hemisphere, for language materials, is somewhat subtle and difficult to obtain under some experimental circumstances.

So while we have a dominance, it's not such a marked dominance, that we can talk about training lateralization as a way to improve reading skills.

MACKWORTH: That's what I was trying to say.

GUTHRIE: I would like to get your reaction to some of the newer techniques ,to measure laterality, for example, visual invoked response procedures, that have been used at Harvard Medical School and other places, to look at learning disabled children. Do you think those are useful or not?

MACKWORTH: Well, I should think so. There is a group in the hospital working with evoked potentials, and they deal with this kind of thing, and I think they also have quite interesting information.

Of course, when you are dealing with brain damage, it is a rather positive thing. It is easy to see, whereas I think small subtle changes in the brain might be quite difficult to locate.

TRABASSO: I am disturbed by the kind of circularity here in the absence of independent information about degree of lateralization, there is tendency in your paper, and also in some of your commentaries in the slides, to make inferences that if one fails in a spatial task, doesn't do well, or takes longer, ipso facto, there is some kind of failure for lateralization to take place. Isn't that a rather dangerous sort of diagnostic?

MACKWORTH: I am not sure I mentioned failure. I am sorry if I did.

TRABASSO: But it does come through, I am afraid.

MACKWORTH: What I was trying to say of the brain damage samples is that we know where their problem is. And we can say that there are low scores on the Patch Test when the right brain is damaged. I didn't mean, really, to carry that over to dyslexics.

TRABASSO: Well, what I am worrying about is kind of convenient biological explanations for failures to read.

MACKWORTH: Well, put it this way, there has to be some reason, and I think it would be a great mistake to say it is this reason or that reason. We don't know.

TRABASSO: These kinds of dichotomies (left-right; skilled-unskilled), when you are dealing with people who show gradations of difference, I find it very hard to conveniently take these distributions of differences on cognitive tasks, and fit them into these convenient dichotomies.

And one of my gut level, emotional responses to your paper, and some of the work on hemispheric dominance in general, has to do with the very strong tendency to classify immediately individuals who differ by matter of degree into these dichotomies. Also, to make strong inferences with respect to underlying biological processes completely ignoring the possibility of learning factors or differential experience.

MACKWORTH: Well, I entirely agree with you, that a lot of factors come into reading.

WEAVER: It's nice to end on a note of agreement.

TRABASSO: Speaker requested his comments be deleted.

June 8--P.M.

COMMENTS BY ETHNA REID

WEAVER: We are very lucky to have with us today Ethna Reid, who is here from Salt Lake City, from the Exemplary Center for Reading Instruction. She will talk to us about the Center.

REID: First, I want to acknowledge that the U.S. Office of Education has provided us with funds over the years, the State School Board of Education, as well as local districts, and research funds have come from the University of Utah, and Dr. Gabriel Della-Piana, very early in the history of our center, was responsible for many of the strategies that we employed in doing research.

Just a comment, I would challenge the "sight approach," as being a visual approach, as it's presented in any basal reader.

Unless we made certain that the child did see the word, there is nothing in a sight approach that ever elicits a visual response. A sight approach is an auditory approach. I don't know why it was every named "sight." When I teach a word by sight, I am very lucky if you look at it. It's just by chance if you do. In order for you to respond appropriately, you just simply have to have auditory sequential memory.

The auditory approach has to have vision attached to it. A visual approach doesn't have to have vision attached to it, or sight approach as it's presently called. You can make it a visual approach by having the children spell, then you know they have seen every letter, or write, and then you know they have seen every letter. Without those tools, you never know, it would not be a visual approach.

And so a phonic approach is far more effective, because you now know for sure, because of their having to sound the letters, they are having to look at each letter in order to attach a sound to it.

But our data very early said that, yes, auditory and visual learners learn more effectively through the phonic approach, because the phonic approach guarantees that sight is involved.

And all of these studies are printed. They are printed in Doctoral and Master's dissertations and theses, and I would be happy to show them. Or the U.S. Office of Education or Educational Testing Service, also have available some of our studies.

One of the earliest questions that we asked ourselves, I guess, was: Are there more or less effective teachers of reading, and since materials don't make differences in reading success, then obviously it would have to be teachers. But how do you isolate the teachers who are more effective and less effective? We had to do it through predictability formulas, and the use of the regression equation in looking at past testing, and identifying those teachers who are teaching like the average of the teachers that taught in the past. But you also can identify those teachers who were teaching above the average, those teachers who take their pupils above prediction. You also can isolate those teachers who do not have their pupils even achieve prediction, or get close to it.

Now, through observational systems of those two extremes, you can isolate characteristics in their behavior, that are different, and this is what we have been spending 12 years doing.

But we have developed, with Brigham Young University, a recording device that I think might be very meaningful to all of you as you do research in the future.

I was really very disappointed, when I saw an NIE contract go out, or a proposal for bids in January for observing videotapes of 400 first-grade and third-grade classrooms next year in the United States, and their observational system was antiquated. It was a paper and pencil procedure where you make tally marks as you see something happen in the classroom. Tally marks, or pushing buttons on counters don't give you sequence, nor will they give you rated data. And if you want to look at effectiveness of prescriptive behavior on the part of a teacher, you have to have sequence, but you also have to have rated data.

Brigham Young University now, with their computer center, has been able to develop a micro computer service through a recorder, that we can connect to either the telephone or else just store it in cassette tapes, and mail the tapes back each night, that gets 100 counts every second. The computer will record simultaneity of behavior. This is exciting, because it's been able in the last year and a half, to do some things for us that we have never been able to do in looking at teacher behavior..

As the data is fed into the computer, we are getting the computer sheets printed out, and in the printout we are even getting standard deviations of the teacher's behavior, as compared to the profile of the effective teacher--so that we can get the statistical data simultaneously, as we are recording the behavior.

We are also counting probably one of the most critical aspects of classtime, and that's lapsed time. It's critical. You wouldn't want teachers to have their day filled with lapsed or nulltime. You get columns of it, of lapsed time:

lapsed time in pupils' responses, lapsed time in teachers' teaching. As you eliminate lapsed time, you change very significantly achievement gains of pupils. Of the data that we get on the computer, probably the most exciting data is the data on when nothing is happening, because you can see great differences in teachers as they go into training to pick up these precise teaching behaviors, one of which is to make certain that pupils do not have lapsed time. You find great differences in the lapses between responses. There is not a great difference in response rates, but great differences in lapses. So the observational systems that we have been using, I think are very exciting. Canada, the Province of Alberta, is evaluating work that we are doing right now in Cardston School Division, in teaching the teachers. The Alberta Province is employing the Brigham Young University evaluation team, as far as monitoring is concerned, to look at the change in teacher behavior that our program is creating, and the report will come out of the University of Edmonton, but it will be the Brigham Young University Computer Center that will be recording the work. We structured a way of looking at maximizing the effectiveness of reading materials. We worked with Ken Goodman many years ago, and realized that materials themselves could build in all kinds of errors. By testing every individual at the end of every story or end of every unit, and the end of every book, and accumulate this over a period of years, we could find those errors that were imbedded through the grammar, through the difference in the way that the author has written, and the children speak, and so on, across books. And after devising this system of maximixing the effectiveness, then we could then create supplementary programs and materials to correct and make more effective materials.

We discovered that we would not have to do this kind of work if we simply expected higher levels of mastery; that you won't have any errors repeated across books, across chapters, across stories, across units, if you achieve 100% mastery on every test that the child takes.

We did a lot of time studies. In fact, the time is so important, that teachers now are allowed only 18 seconds to 55 seconds to diagnose and prescribe for the reading error that occurs. Any longer than that, you won't get a statistically significant change in reading achievement. So we teach the teachers not to rely on commercially prepared materials. Although we, you know, let school districts and schools use whatever material they presently have, we add mastery testing to it. One of our studies, John Allen's Doctoral dissertation took 4,004 third-grade students in the State of Utah. The Gates-MacGinitie was administered to all 4,000. All those who failed to read the first-grade level paragraph were individually tested on basic visual and auditory skills. We also had four years of preschool studies. We wanted to find out which, was the best age to introduce academic instruction. We had 330 three-year-olds and four-year-olds, and a corresponding number of five-year-olds and six-year-olds. We put them in the same identical program of academic instruction, and the same amount of time, the first year, the second year, the third year, the fourth year. Our data after a period of four years indicated that the younger that you began to teach them, the easier it is to teach them, and the greater gains that are made in instruction. But we did find out, from those early studies, how easy it was to teach visual and auditory discrimination, and other necessary basic skills, which would be preparatory for reading. Although in both of those studies, we just taught them reading with the teachers employing the critical teaching techniques.

We have had a lot of studies with behavior modification. One of the early factors that we isolated in this effective teacher was the ability of the teacher to promise contingencies and carry them out. And one of the more exciting ones, the Alder study, we got some data that we didn't anticipate. We asked third-grade children to identify what they really would work for. Could they identify what they liked to do best and how they were spending the greatest amount of their time? We had interviewers interview them, classify their responses and rank order them.

We interviewed the teachers and asked the same questions. Now, these were third graders who were not learning to read; these were the children who were having difficulty in the classroom. The teacher's list did not correlate at all with the children's list. In fact, the teachers became very indignant when they saw the children's ranking.

For instance, those children who stated they spent the greatest amount of the day doing math, they said, "It is impossible, we only have 50 minutes of math a day, they don't know what they are talking about."

Then we had a cartoonist cartoon every activity we picked up in either list from all of the third graders. Then these were put in slides, and then were presented in paired presentations, "Which do you like to do best, A or B?" And of course their choices were the same! But that still didn't mean that's what they were doing each day in the classroom.

We then sent observers in the classrooms, and they spent three weeks observing each child, and sure enough the children were actually doing what they had identified they were doing, and spending the greatest amount of time during the day doing the thing they liked best to do. Now, that became contingent upon their doing reading first.

The outcome of the study was whenever a child preferred a "goof-off" activity, something that was not a curricular activity, such as sharpening his pencil, or cleaning his desk, or talking to his neighbor, additional recess, when that became contingent upon doing reading, it lost its reinforcing properties, and we had to identify with the child a new reinforcer. And in every instance it became another academic activity. This was very exciting for us, because if you can reinforce one curriculum activity with another, you get a much greater gain in both activities.

We have done a lot of work, and I will just close with emphasizing how important it is to teach so no one makes errors as he learns. As the teacher teaches comprehension skills, study skills, word recognition skills, all of your language arts skills, he must move from what I call a model match level of learning to a memory match level to a pure recall level of learning.

We found it very easy to ~~teach children~~ to read words, but we discovered that it was not as easy to teach some of the comprehension skills, because we never really taught comprehension skills. But only questions have been provided for us to test for comprehension. Questions give us a way to test, but not really how to teach. We have directives to teach many of the comprehension skills. And the exciting part is that these directives do not allow errors. Larry Reynolds has a beautiful study identifying that the fewer errors teachers allow, the finer discriminations children are able to make. The ECRI program does not allow an incorrect response.

The nicest thing about doing our research is that at the same time, in order to support ourselves, we were also contracting services with local school districts. For a long while we were upset because we were doing a great amount of work, but now we are very grateful, because we have been able at the same time that we were obtaining information from research, we have been able to put it into classroom practice. You could visit some of the school districts now, where teachers are using products of research, and right now in those particular schools and classes we don't have any reading failure.

And when Mike was talking about 86% success, I can talk about 100%. But it's because of the many, many years of work and opportunity to really look at what happens to children, where teachers' behavior is affected over a long period of time.

One of the studies at Indiana University was that it wasn't as important how long the children had been in the program, as how long the teachers had been in the program, and it took teachers a second year to be in the program before they had incorporated these critical teacher behaviors that helped to make them effective.

END SESSION